

REMARKS

1. Applicant acknowledges the Examiner's rejection of claims 3, 5-8, 10, 13, and 16 under 35 U.S.C. § 112, second paragraph, as being indefinite. Claims 3, 5-8, 13, and 16 are currently amended to remove the parentheses in order to make clear that the parenthetical limitations were part of the claim. The rejection of claim 10 is respectfully traversed, because no parentheses are present in that claim.

2. Applicant acknowledges the Examiner's rejection of claims 1-16 under 35 U.S.C. § 103(a) as being unpatentable over Yamell et al. (US 5,610,217) in view of Lee (US 5,135,687), but respectfully traverses this rejection.

The Examiner suggests that it would have been obvious to modify the cord of Yamell et al to include the fibers (which I will call "PVP/aramid" fibers) as taught by Lee in order to improve strength, but no direct citation to the prior art is provided where this suggestion is found. On searching the Lee disclosure, Applicant finds several possible passages which the Examiner might be referring to, and these will be addressed in turn.

First, Lee makes mention of improved tenacity retention as a result of heat treatment conducted at 250°C to 550°C (col 3 line 60 to col 4 line 3). This statement is not sufficient motivation to combine for several reasons. (1) The Applicant could find no supporting data for this claim in Lee, other than Lee's generalized statement. Moreover, contradictory statements to the effect that aramid fibers do not suffer from poor tenacity retention on heat treating are found in general reference books.

"The mechanical properties of aramid fiber may be further improved by heat treatment under tension. ... Major increases begin at about 360°C, and properties maximize at about 550°C. ... Such after-processing of a wet or dry spun yarn can produce only high-modulus, high-strength variants (Kevlar 49®) as both properties increase simultaneously." (Michael Jaffe and R. Sidney, "High Performance Aramid Fibers," in Menachem Lewin & Jack Preston, eds., "Handbook of Fiber Science and Technology: Volume III, High Technology Fibers Part A," Marcel-Dekker, NY, p 383 (1985) (emphasis added).

(2) It was also known by those of ordinary skill in the art that such heat treatment with its alleged tenacity decrease is not applicable to aramid fibers intended for use in power transmission belts. As stated in the application, "the cord is generally passed through

an oven or a series of ovens at temperatures from 100°C to 260 °C to dry and cure the adhesives" (page 11 line 4-5), which is a much milder condition than referred to by Lee, or than required by the reference book quoted above. In other words, belt companies heat aramid cords just to dry the adhesives (at about 220°C typically), and don't "heat treat" the fiber at 360-550°C to enhance tensile properties. (3) The Applicant's personal experience contradicts Lee's statement about heat treatment tenacity losses in aramid, at least under conditions applicable to belt making. The data in Table A below was measured by the Applicant on the same examples disclosed in Table 1 of the application and at the same time. It is clear that the treatment done to the prior art aramid cord in preparation for use in a belt had only a small (and quite normal) effect on tenacity – not a problem demanding a solution. In addition, the PVP/aramid fiber was slightly *more* affected than the aramid fiber. Thus, an unsupported claim of improved strength retention after heat treatment would provide no motivation to one of ordinary skill in the belt art to combine Lee and Yarnell et al.

Table A.

Example	Fiber of Cord	Twisted Greige Yarn Strength (lbs)	Treated Cord Strength (lbs)	% Strength Retention
Trial 1, Example 1	PPD-T /PVP	145.3	133	91.5%
Trial 1, Comparative Example A	PPD-T	139.9	130	92.9%

Second, Lee discusses improved heat aged strength retention after heat resistance testing at 240°C (col 7 line 6) and improved resistance to burning, both of which tests are conducted under conditions and for purposes inapplicable to the power transmission belting of concern to the Applicant. It is well known by those with ordinary skill in the art that the heat resistance demand on belts of the present invention is generally limited to 140 to 150°C max. As stated in US 5,698,650 regarding elastomers for use in belts (at col 1 line 47-51). "The engine compartment temperature may reach 120° C. and often may reach 140° C. or even 150° C., generally when the vehicle stops after operation and no cooling is exerted from the outside air flow as would be experienced during moving operation." Thus, a suggestion that a fiber has improved

heat aged strength retention at 240°C and/or improved fire resistance, while applicable to fire-fighter fabrics, would not motivate an ordinary belt designer to use it.

Third, Lee makes a vague reference to "tensile properties which are improved" (col 1 line 15) which might refer to higher tenacity, increased modulus, or perhaps even the heat aged strength retention discussed above. Regarding higher tenacity, the Applicant finds in Lee, in Tables 2 and 3, only a single example (out of eleven examples) where the inventive fiber has a higher tenacity than the control aramid fiber. The increased tenacity is only 23.9 gpd versus 22.5 gpd for the control, and this increase is not highlighted as being very significant in the Lee disclosure. On the other hand, Lee does say that "PVP adds very little to the strength of the fibers compared with the contribution of the PPD-T" (col 6 line 13-15), thus discouraging use of PVP/aramid fibers for strength or tenacity improvement alone. Regarding the possibility that improved tensile properties might refer to increased modulus, it is noted that example 1 in Table 2 also increased modulus as well as increased tenacity. However, it is also known by those with ordinary skill in the art that increased-modulus fibers generally suffer from inferior flex-fatigue resistance (see application page 1 line 21-23; see also US 5,151,142 col 3 line 1-7 where it states "the rubber-reinforcing fiber cords which are made of such conventional high tenacity and high elasticity [ie modulus] fibers [like PPD-T aramid] having a low elongation and useful as cords for reinforcing a variety of rubber articles such as tires, belts, hoses, rubber crawlers, etc. unfavorably have poor fatigue resistance, particularly poor compression fatigue resistance." (emphasis added)). Thus, not only would one skilled in the belt art not expect a higher-modulus, higher-tenacity fiber to have improved performance in a belt, but tensile properties simply are not as relevant as compressive properties for predicting performance in belts. Lee makes no mention of compressive properties of PVP/aramid fibers.

As another illustrative example of an "improved" fiber having poor flexibility, see US 6,132,328 col 1 line 42-47. There it states "To improve the dimensional stability over time, JP-A-50-16739 discloses a rubber reinforcing material, having good heat resistance and good dimensional stability, using polyethylene-2-6-naphthalate (PEN) fibers. However, bending fatigue is generally poorer with this type of fibers than with PET fibers." Thus, in an analogous way, a new polyester fiber with improved tensile

properties (PEN) proved to have inferior bending fatigue properties in belts compared to the material it was supposed to improve upon (PET).

It should be appreciated that to those skilled in the art, improved belt flex fatigue is a primary and general concern, for example to improve belt life on existing drives or for use of existing belts on drives with smaller-diameter pulleys. (See for example Yarnell et al. col 1 line 40; US 5,807,194 to Knutson et al. col 1 line 14-15; and references cited above). Thus, while the Applicant was motivated to find a fiber for power transmission belt tensile cord that provided improved *flexibility* or *flex fatigue* properties over aramid cord, there was no perceived deficiency in the *tensile* properties of aramid fibers for belt applications, and no relevant suggestion from Lee to use PVP/aramid fiber in belts for flex-fatigue improvement. Furthermore, the Applicant had no reasonable expectation of success in improving the flexibility of aramid belts based on the disclosure of Lee.

Moreover, the Applicant found significant, unexpected results upon incorporating PVP/aramid fibers in load carrier cord for power transmission belts. In evaluating the new fiber in belts, the Applicant found that the tensile properties of the inventive belts were comparable to, but not superior to, conventional aramid belts (Table 1-2, and page 15 line 12-14). Neither was there any improvement in adhesion to the belt elastomer as determined by peel tests (page 13 line 20-25). In other words, the claims of Lee were found to be no more than "puffing" as far as use of PVP/aramid in belts was concerned. Thus, it was quite surprising and unexpected to find that the inventive belts exhibited significant improvements in both durability and flexibility (page 15 line 12-18, page 16 line 5-6, and Tables 1-2).

In light of the above, the Applicant respectfully requests that the obviousness rejection be withdrawn and all claims be allowed as currently amended.


3. The Applicant acknowledges the three additional prior art documents made of record but not relied on by the Examiner. These three references are felt to be less pertinent to the claimed invention than those relied upon by the examiner.

FEE STATEMENT

Any fees which may be required as a result of the amendments made herein, are authorized to be charged to Assignee's deposit account number 07-0475.

In light of the forgoing amendments and remarks, favorable reconsideration of the allowability of all claims is respectfully solicited.

Respectfully submitted,


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Dated: 10 April 2006

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enc - title page and pp 383-389 of Michael Jaffe and R. Sidney, "High Performance Aramid Fibers," in Menachem Lewin & Jack Preston, eds., "Handbook of Fiber Science and Technology: Volume III, High Technology Fibers Part A," Marcel-Dekker, NY (1985).

Handbook of Fiber Science and Technology: Volume III

HIGH TECHNOLOGY FIBERS

Part A

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ABOUT THE SERIES

When human life began on this earth, food and shelter were the two most important necessities. Immediately thereafter, however, came clothing. The first materials used for it were fur, hide, skin, and leaves—all of them sheetlike, two-dimensional structures not too abundantly available and somewhat awkward to handle. It was then—quite a few thousand years ago—that a very important invention was made: to manufacture two-dimensional systems—fabrics—from simple monodimensional elements—fibers; it was the birth of textile industry based on fiber science and technology. Fibers were readily available everywhere; they came from animals (wool, hair, and silk) or from plants (cotton, flax, hemp, and reeds). Even though their chemical composition and mechanical properties were very different, yarns were made of the fibers by spinning and fabrics were produced from the yarns by weaving and knitting. An elaborate, widespread, and highly sophisticated art developed in the course of many centuries at locations all over the globe virtually independent from each other. The fibers had to be gained from their natural sources, purified and extracted, drawn out into yarns of uniform diameter and texture, and converted into textile goods of many kinds. It was all done by hand using rather simple and self-made equipment and it was all based on empirical craftsmanship using only the most necessary quantitative measurements. It was also performed with no knowledge of the chemical composition, let alone the molecular structure of the individual fibers. Yet by ingenuity, taste, and patience, myriads of products of breathtaking beauty, remarkable utility, and surprising durability were obtained in many cases. This first era started at the very beginning of civilization and extended into the twentieth century when steam-driven machinery invaded the mechanical operations and some empirical procedures—mercerization of cotton, moth-proofing of wool and loading of silk—started to introduce some chemistry into the processing.

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Library of Congress Cataloging in Publication Data
(Revised for volume III, Part A)

Main entry under title:

Handbook of fiber science and technology.

(International fiber science and technology series ;

1-)

Vol. 3 edited by Menachem Lewin and Jack Preston.

Includes bibliographical references and indexes.

Contents: v. 1. Chemical processing of fibers and fabrics--fundamentals and preparation --v. 2.

Chemical processing of fibers and fabrics--functional

finishes --v. 3. High technology fibers.

1. Textile finishing. 2. Textile fibers.

1. Lewin, Menachem, [date] II. Sello, Stephen B.,

[date]. III. Series: International fiber science and

technology series ; 1, etc.

TS1510.H3 1983

677.02825

83-7685

ISBN 0-8247-7279-2 (v. 3, pt. A)

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MARCEL DEKKER, INC.

270 Madison Avenue, New York, New York 10016

Current printing (last digit):

10 9 8 7 6 5 4 3 2 1

PRINTED IN THE UNITED STATES OF AMERICA

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(83 rpm) vertically through a 0.5-cm layer of air into 1°C water. The yarn is wound up at different speeds on a bobbin under a water (50°C) spray. The bobbins are then submersed in 0.1 N NaHCO_3 and then further extracted with water (70°C) on an advancing reel extracting device of the type shown in U.S. Patent 2,659,225. The extracted yarn is wound up and dried on the bobbins at 70°C. Properties of the dried yarn of 5.2 IV are given in Table 9.6, items a, c, and d.

Note the complicated dope mixing and atmospheric protection procedures that are necessary because of sensitivity of the dopes to water (<2% specified) and the different types of mixing of the $\text{PPT}/\text{H}_2\text{SO}_4$ dopes in the high-viscosity region before mesophase formation. Dope uniformity is essential to successful spinning. This example also illustrates that by varying the SSF from 1.45 to 4.35, products covering a modulus range of 517-948 gpd at essentially constant tenacity (ca. 23 gpd) can be produced in spinning. Anisotropic PBA dopes in tetramethylene/LiCl can be dry spun to yield fibers with strength and moduli between those achieved by wet and dry jet-wet spinning [8]. Table 9.7 lists the properties achieved with low-IV PBA as a function of SSF. These data fall on the modulus orientation angle plot shown in Fig. 9.24. Low solubility of PPT in tetramethylene/LiCl precludes this approach commercially.

3.4 Aramid Fiber Heat Treatment

The mechanical properties of aramid fiber may be further improved by heat treatment under tension. The response of differently spun PPT yarns to heat treatment is shown in Fig. 9.39. In wet spun yarns both tenacity and modulus increase exponentially with increasing temperatures (and draw ratio). Major increases begin at about 360°C, and properties maximize at about 550°C. These temperatures have been identified as T_g and T_m of PPT, respectively [39,39,55]. Figure 9.34 shows that the properties of dry spun PBA increase in a similar fashion [8]. Such after-processing of a wet or dry spun yarn can produce only high-modulus, high-strength variants (Kevlar 49) as both properties increase simultaneously. During the heat treatment, wet spun yarns show major increases in crystallinity, structural perfection, and orientation. In addition, a transformation of the crystallographic unit cell to that observed in dry jet-wet spun PPT is noted, as shown in Fig. 9.35. In dry jet-wet spun yarns, a jump in modulus is observed, essentially independent of temperature at temperatures greater than about 280°C. The final modulus level is a function of the precursor modulus (or orientation), as shown in Fig. 9.36, with tenacity remaining essentially constant. A moderate increase in structural perfection is noted after treatment, as illustrated by the density increases plotted in Fig. 9.37.

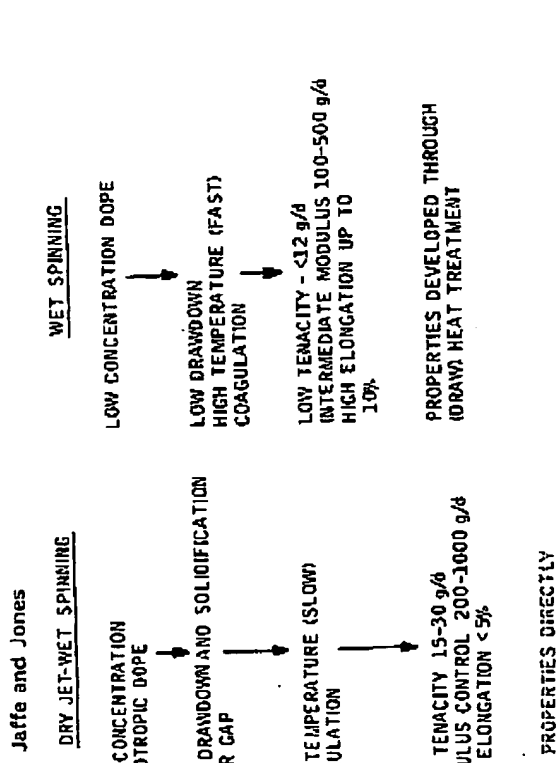


Fig. 9.32 A contrast of the dry jet-wet and wet spinning processes producing PPT fiber. (Courtesy of the Celanese Research Company, Unit, NJ.)

Polyphenylenediamine terephthalamide (PPT-T) of 6.9 IV is added to sulfuric acid (99.7% H_2SO_4) at 40°C in a water-jacketed commercial planetary mixer through a top entrance over about 2 min to give a ratio of 45 g of polymer/100 ml of acid. The mixer is sealed and placed under 68.5-76 cm Hg vacuum. The temperature of the water jacket is increased to 85°C and the planetary mixing blades started at a slow speed. After about 12 min the jacket temperature is reduced to 70°C, which affords a temperature in the solution of between 79 and 83°C. Mixing is continued for about 2 hr. The solution then has a bulk viscosity of 2300 poises.

The dope is transferred to a glass-lined, water-jacketed (90°C) kettle. A vacuum of about 68-76 cm Hg is applied for about 30 min to remove any air or bubbles caused by the transfer. The dope is pumped from the kettle through a transfer line closely wrapped with a water line (90°C) to an electrically heated (80°C) spinning block and attached gear pump. The gear pump meters the dope back through another passage in the block to a water-jacketed (80°C) spinnerette pack containing a backing screen, stainless steel felt, and a 0.5 in (12.5 mm) diameter spinnerette containing 100 holes of 2 mil (0.051 mm) diameter. The dope is extruded from the spinnerette at a jet velocity of about 207 fpm

Item	Heating conditions (°C-t-tens) ^a	Yarn properties					Denier per filament
		Tenacity (gpd)	Elongation (%)	Initial modulus (gpd)	Toughness (g-cm/d-cm)	Denier	
a	None	21.2	3.9	547	0.39	415	3.7
a-1	250-6-6	21.4	2.3	917	0.24	394	3.9
b	None	22.0	3.3	649	0.34	196	2.0
b-1	350-1.5-4	22.3	2.2	1019	0.24	179	1.8
c	None	22.8	3.2	727	0.35	190	1.9
c-1	250-6-4	23.1	2.2	1080	0.27	178	1.8
d	None	24.8	2.8	948	0.34	135	1.4
d-1	250-3-6	22.5	2.0	1175	0.23	136	1.4
d-2	550-6-2	16.8	1.3	1394	0.11	136	1.3
e	Dried 150°C	23.6	2.9	862	0.35	184	1.8
e-1	400-3-4	20.5	1.9	1080	0.19	179	1.8
f	None	25.1	3.2	779	0.39	191	1.9
f-1	350-1.5-6.5	23.9	2.1	1130	0.25	177	1.8

a / Jaffe and Jones

^a°C = temperature of wall at midpoint of the tube; t = treatment time (sec); "tens" = tension (gpd).
 Source: Ref. 44.

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Table 4.7 Properties of Undrawn Dry Spun Poly(1,4-benzamide) Fiber

Spin stretch factor ^a	Denier	Tenacity (gpd)	Elongation (%)	Initial modulus (Gdp)	Orientation angle
Free fall	6.0	3.2	3.7	140	39°
1.90	6.1	3.9	2.7	235	37°
2.42	4.8	4.2	3.4	220	38°
2.56	4.5	5.5	3.3	280	26°
3.83	3.1	6.9	2.9	390	22°
5.11	2.3	8.6	3.0	470	22°
6.39	1.9	8.0	2.8	430	19°

^aSpin stretch factor is windup speed/linear extrusion rate. Polymer $\eta_{inh} = 1.48$ (H₂SO₄). Spin dope = 13% in tetramethylurea/LiCl (6.54%). Fiber crystallinity is medium. Orientation angle was determined by x-ray [11].
 Source: Ref. 8.

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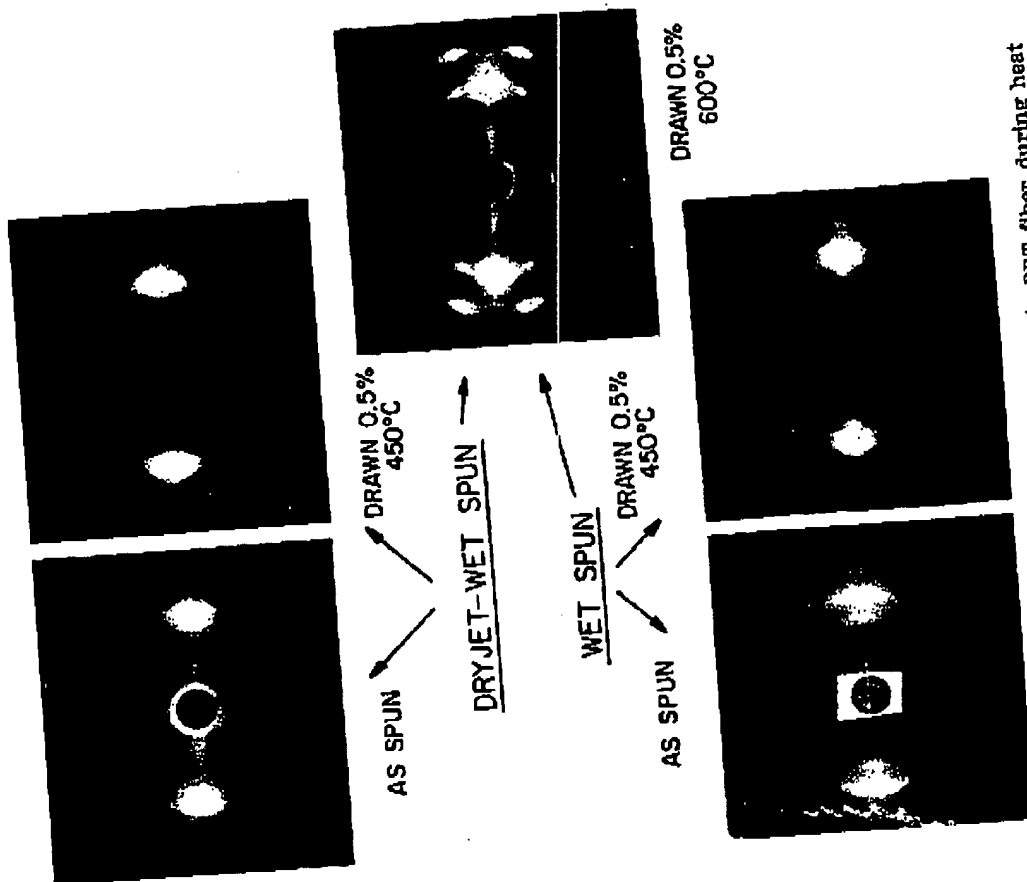


Figure 9.35 Structural changes occurring in PPT fiber during heat treatment as shown in the resulting wide-angle x-ray diffraction patterns. (Courtesy of the Celanese Research Company, Summit, NJ.)

Figure 9.34 Effect of heat treatment on the properties of poly(1,4-benzamide) fibers. (From Ref. 8.)

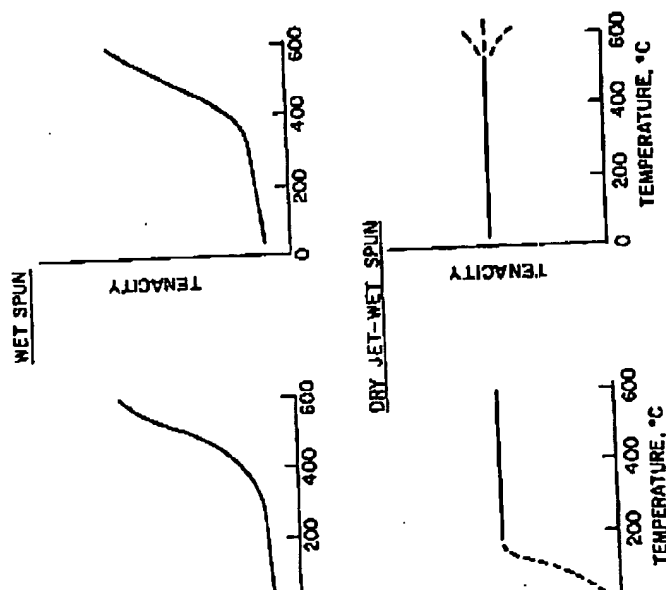
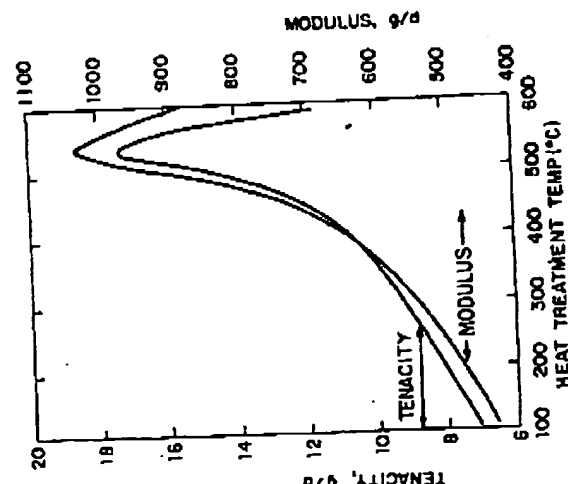


Figure 9.33 Schematic representation of the response of dry jet-wet and wet spun PPT fiber to heat treatment. (Courtesy of the Celanese Research Company, Summit, NJ.)



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as a function of heat treatment temperature. Hence, an intermediate-modulus, high-strength, dry jet-wet spun yarn can be easily transformed to a high-modulus variant through thermal treatment. All these changes are physical; the IV of the treated yarns remains constant. Typical commercial conditions for the heat treatment of PPT as described in U.S. Patent 3,869,430 [44] are as follows.

This example illustrates the heat treatment of fibers of PPD-T in order to increase the initial modulus.

Fibers are extruded from dopes with sulfuric acid using the general procedures of Example 1. [See Extract, p. 382]. Items e, c, and d of Table 9.6 are the fibers of Example 1. Yarn item e is dried under a tension of 5 gpd at 150°C. Yarn item f is prepared from polymer of 6.6 IV.

Yarn IV values range from 4.9 (item b) to 5.8 (items f and f-1).

The well-washed and dried yarns of about 135 to 415 denier (100 filaments) are passed through a 10 ft long (3.05 m) stainless steel tube of about 1.5 cm I.D. containing nitrogen at various conditions as given in Table 9.6 under "Heating conditions".... The tube is electrically heated and is contained in a box of vermiculite as insulation. The nitrogen passes through a tube in the box before being fed to the yarn treatment tube. The yarns are only drawn from about 1.001 to 1.021 times their original length and do not contact the walls of the tube.

Similar results are obtained when a water-wet yarn is treated in this manner.

It is observed that with a 400 denier yarn the temperature should be about 100°C higher than that used for a 200 denier yarn when treatment times of about 1 sec are used.

3.5 Conclusions

1. Modulus development in as-spun PPT fiber is dependent on the total spinning strain and is essentially independent of IV and air gap. As-spun moduli covering the range of about 100-1000 gpd may be achieved directly by dry jet-wet spinning.

Figure 9.37 Structural changes occurring during PPT heat treatment. Density development as a function of heat treatment temperature. (A) MODI = 700 gpd; (B), MODI = 350 gpd. (Courtesy of the Celanese Research Company, Summit, NJ.)

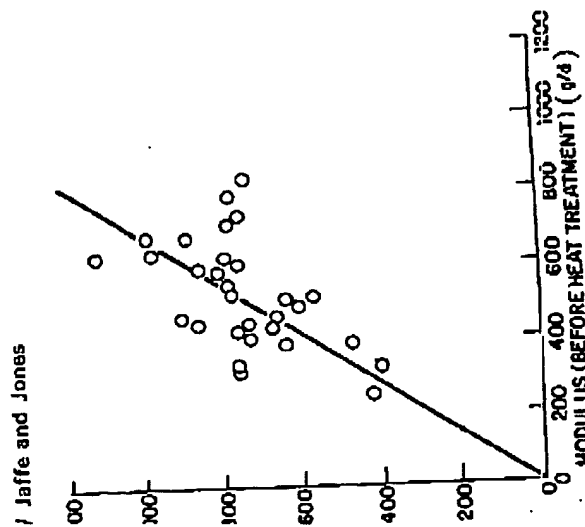
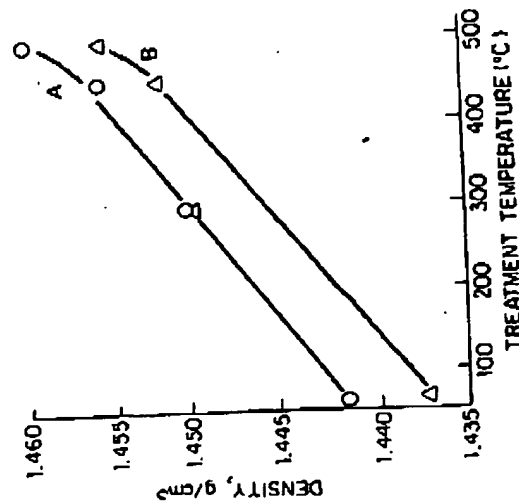


Figure 9.36 PPT fiber modulus after heat treatment as a function of modulus level before heat treatment. Dry jet-wet spun fiber; heat treatment temperature, 250-500°C. (Courtesy of the Celanese Research Company, Summit, NJ.)



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